RESEARCH ARTICLE

AkwaIbom (Iba Oku) Clay as Extender Pigment in Formulation of Anti-Corrosive Alkyd Paints for Saline Medium

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ABSTRACT: Akwaibom (Iba Oku clay) was employed as a pigment extender to produce alkyd paints with mild steel-friendly anti-corrosive properties. 0.075 mm of this clay particles were employed as extender contents ranging from 0 to 80.0 weight percent. Reference alkyd paint was produced with titanium dioxide, and xylene. Main ingredients found in this clay in wt.%, where silica (58.19), alumina (35.35), titanium dioxide (2.60), and traces of other metallic oxides. From the study this clay was stable to heat and chemical medium. Products painted with the sample paint had satisfactory surface and complete drying times with best complete drying time gotten at 220 minutes for 80 wt.% clay. The paint film thickness was between 0.10 and 0.15 mm, showing abilities to give weather-resistant barriers and good impact resistance. The quantity of clay in the dry paint film increased the hardness of the paint film giving a maximum pencil hardness of 5H for 60 and 80 wt.% clay. General adhesion of the paint dry coatings on mild steel surface was in the range of 3.0 to 25.0%. Neither blistering, nor serious paint defects were seen on immersion into 2.5% NaCl, except minor color changes due to anti-corrosive properties inherent in it. This is in contrast to the performance at 2.5% for H2SO4, where some notable paint flaws occurred while 2.5% Na2CO3 was generally satisfactory. This study gives value to this clay as an extender pigment suitable in the formulation of paints for the protection of mild steel in saline conditions.

KEYWORDS: Extender, Alkyd Paints, Akwaibom (Iba Oku) Clay, Titanium Dioxide, Particle Size

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1. INTRODUCTION

Paint is any substances that have a pigment suspended in a liquid or paste. Paint offers an economic protection, decoration, aesthetic and adds functionality to structures [1]. The Composition of paint largely depends on its characteristics, usage and classification. Variation in the proportion(s) of the various constituents, paint can be made dry, glossy or flat, just as other properties such as permeability to water and anti-corrosiveness to steel could be varied as well [2]. Relationship exists in the characteristics of clay (kaolin clay), and extender pigment (calcium carbonate) used in the production and formulation of synthetic pigmented paint [3]. Clay paints do not pollute the environment unlike the household conventional chemical paints, but regulate humidity, control condensation and are anti-static because they do not contain any plastics and attract little or no dust.

Clays has been used majorly as extenders in architectural and industrial paints formulations, and its use have been seen in other industries like in agriculture, in construction as a building material, in oil industry as drilling muds to protect the cutting bit while drilling, filtering and deodorizing agents in the refining of petroleum, in clarifying water and wine, in purifying sewage as an adsorbent, in textile and sugar industries to remove colour and other impurities, and in the paper, plastics, and rubber industries as fillers [4]. Titanium dioxide (TiO_2) has been the most notable used pigment in coatings.

Clay refers to variety of fine-grained earthen materials that when heated or baked, becomes hard and flexible when moist. They are hydrated aluminum silicates with chemical formulas of Al2O3.2SiO2.2H20 with small quantities of potassium, sodium, calcium,

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magnesium, or iron which are impurity. They are natural occurring and one of the main minerals that are widely distributed in earth's crust [4]. It is believed that clay is a product of hydrothermal activities and rocks (often silicates)weathering by low concentrations of carbonic acid and other diluted solvents at various points in the geochemical cycle[3,5]. Clay has color range from drab grey to rich orange red depending on the amount of soil present. Clays' physical characteristics, such as their hardness, cohesiveness, flexibility, and drying shrinkage, do vary greatly with location(s) which is dependent on their size, layered structure, and chemical makeup [5]. The ability to exchange ions and have strong affinity for water are characteristics shared by all clay minerals reported [6].

Many minerals and vegetable oils are processed using fuller's earth [7]. Ahmed [8] studied the variation in performances that existed between natural kaolin, thermally treated kaolin (calcined kaolin), and chemically treated kaolin in formulated alkyd based paint in the protection of steel. Their study showed that calcined kaolin performed better in preserving steel than kaolin, while chemically treated kaolin varied in its performance according to the concentration of the modifier used. They suggested kaolin can act as a reinforcing agent in polymer compositing. Ewulonu [9] synthesized and characterized local clay-titanium dioxide core-shell extender pigment employing simple chemical technique and determined their combined properties of both the local clays and titanium dioxide. Improvement of the thermal degrading property of polyacrylonitrile/nano composite filaments by using montmorillonite clay was investigated and reported that fibers with higher montmorillonite clay concentrations showed more crystallinity Rahim M. et al [10]. the use of clays as extenders in paint formulation of been of recent interest to paint formulators and technicians who seek out for technically sound alternatives to titanium dioxide (TiO2), the main primary pigment used in surface coatings, in order to reduce the price of paintings to reasonable levels and give economy to natural clay. The most often used pigment in paint formulas is TiO2, a white pigment with a high refractive index and highly expensive too. TiO2 undergoes photo catalytic effects leading the surface degradation of paint due to the chemically active nature of pigment [11].

Clay is employed to formulate paint that is less expensive with little opacity to paint films. Calcined clays are being explored as TiO2 substitutes in paint compositions since they are economical and environmentally beneficial. Fine calcined clays function as a spacer to TiO2, which increases its ability to scatter light while maintaining good paint dry film opacity [10, 11]. Reports of local Nigerian clays being used as extenders in paint formulation especial in alkyd paints having satisfactory coating qualities have been published [12]. Narayan and Raju [13] prepared two latex paints based on a calcined clay and reported that the clays can replace up to 20 % titanium dioxide in paint formulations without having any negative effect on paint properties. Solvent-based paints with pigment concentrations of between 50 and 75 percent have been created using ferrite-kaolin hybrid pigments [14]. Igwe et al., (2021) used Umuahia clay to produce alkyd paint. They reported that paints showed strong scratch resistance, excellent gloss, and great obliterating value. Alkyd-based paints prepared with ultrafine kaolin were capable of replacing up to 10% of the TiO2 in the formulated paints with no loss of opacity, whiteness, or gloss [15]. The incorporation of the clay also improved the sagging resistance of the formulated paints. When used on steel substrates, the produced paints demonstrated good corrosion protection properties. In this study, clay from Iba Oku, Akwaibom, Nigeria was employed as a pigment extender to formulate alkyd paints that have anti-corrosion qualities when used on mild steel surfaces. The concentrations of the pigment extender was ranged between 0 to 80 weight percent, the clay that was calcined at temperature 850°C having 0.075 mm particle size. Alkyd paint made using TiO2 was used as reference paint and the solvent used was xylene. This study is aimed at giving economy and offer better alternate option for TiO2 extender for this clays domicile in abundance in the South-South region of Nigeria for paint manufacture and for industrial use, whilst adding to knowledge to what has been done so far by other researchers in this area.

2. MATERIALS AND METHODS

A. Materials Used

The following materials were used in this study.

Alkyd Resin: This medium-sized soybean oil alkyd resin was bought from chemical store in Onitsha, Nigeria. It has a 2.30 mg/g KOH acid number.

Clay Sample: To be employed as an extender, clay was obtained from Iba Oku, AkwaIbom, Nigeria.

Figure 1: Raw Akwaibom (Iba Oku) Clay

Cobalt CAS 7440-48-4 and lead naphthanates CAS 1330-20-7, which were employed as driers, were acquired at a chemical store in Onitsha, Nigeria. The surface drying of the prepared paintings was done with a cobalt dryer, and the thorough drying was done with a lead naphthanate dryer. Their respective metal compositions are 36% lead and 12% cobalt.

Toluene (JHD) CAS 108-88-3, chloroform (JDH) CAS 67-66-3, methanol, xylene (BDH), sulphuric acid CAS 7664-93-9, hydrochloric acid (M&B), acetic acid (BDH), sodium hydroxide, ammonia, titanium dioxide (M&B), linseed oil, and stearic acid were the analytic grade solvents and reagents utilized in this work without purification.

B. Methods Applied

Extender Preparation: The sample clay it's the extender. Firstly, impurities were removed followed by the sun drying of the Akwaibom (Iba Oku) clay. It was then sieved to obtain a particle size of 0.075 mm, motorized grinder was employed to crush the clay to fineness, and then heated with an oven to the temperature of 150°C for 12 hours this is to reduce its moisture content. The clay was sieved and canned in a jar with a tight lid read to use for the study.

Characterization of Clay Used as Extender:

characterization evaluation was done for its specific gravity (ASTM D 153-84), pH (ASTM D 1208-960), refractive index (ASTM D1208-96), oil absorption (ASTM D 281-12), and chemical composition (ASTM D 5381-94) employing industrial standard techniques for the sample clay. The chemical resistance of the clay was analyzed; 50 cm3 beaker containing 1 g of sieved Akwaibom (iba oku) clay was filled with 10 cm3 of the test chemicals which were, chloroform, hydrochloric acid, toluene, sodium hydroxide, and ammonia solution . The clay-filled beaker was gradually heated with observations recorded for possible color changes and solubility between being cold and being heated.

Alkyd Paint-Akwaibom (Iba Oku) extended Sample Preparation:

Xylene, medium soya bean oil alkyd resin, titanium dioxide (TiO2) and investigated clay extender were used to formulate paint samples. Titanium dioxide (TiO2) served as a pigment extender in the control alkyd paint sample of which it would be replaced with the natural clay sample. Xylene was the diluents or solvent in the paint samples. The numerous sample formulates of alkyd paint that were examined are displayed in clay.

Table 1: Formulation of Alkyd Paint Samples Ingredients

SAMPLE CODE	ALKYD RESIN	XYLENE	TiO2	CLAY
APT100	66	0.00	12	29.6
APT-AK -80/20	66	5.80	11.9	23.8
APT-AK -70/30	66	9.90	11.9	19.7
APT-AK -60/40	66	11.8	11.9	17.8
APT-AK -50/50	66	14.8	11.9	14.8
APT-AK -40/60	66	18.0	11.9	11.6
APT-AK -30/70	66	20.0	11.9	9.6
APT-AK -20/80	66	23.9	11.9	5.7

Amount of lead drier used = 0.15g
Amount of cobalt drier used = 3.00g
Pigment/Binder Ratio = 0.5

Note: APT = Paint sample containing 100% TiO2. APT-AK = Paint sample formulated using TiO2 and Akwaibom (Iba oku) clay

Characterization of Alkyd Paint Samples:

The prepared alkyd paint samples were characterized for the surface dryness time and the complete drying time. The dry paint film thickness (ASTM D 1005-95), dry paint film hardness (ASTM D 3363-05), and impact resistance of dry paint films (ASTM D 2794-93) of the prepared alkyd paint samples were characterized for using standard methods. Surface dryness was considered when finger without pressure runs over the dry paint film on mild steel and when the finger picks up no paint from the wet paint surface. The paint was considered complete drying when maximum pressure is applied without no loosening, detachment, wrinkling or other evidence of distortion of the paint film after being pressed maximally with the finger. 2.5% H_2SO_4, 2.5% NaCl, 2.5% Na_2CO_3, and deionized water were used to evaluate the adhesion of dry paint films on mild steel panels, and media resistance of dry paint films on water were determined using the ASTM D 6677-07, 2012, and NIS 268: 1989 methods respectively.

3. RESULTS AND DISCUSSION

Characteristics of Akwaibom (Iba Oku) Clay

Akwaibom (Iba Oku) clay used in formulation of the alkyd paints has the following properties:

pH:

The clay has a pH of 6.25, an indication that it is moderately acidic. The pH of some paint extenders are Okposi clay, 7.45[18], Okigwe - Mbano clay, 6.0[12] fly ash, 8.15[21].

Refractive Index:

Generally, extenders do not give opacity or colour when added to paints. Abbe's refractometer was employed in the evaluation of the refractive index of Akwaibom (Iba Oku) clay and was found to be 1.68. The refractive index of an extender pigment always affects the refractive index of paint. The refractive index of extender pigments are in the range1.45-1.65. The refractive index of titanium dioxide (2.75) used in this study is higher than that of Akwaibom (Iba Oku) clay. Many extenders used in coatings give lower refractive indices with respect to titanium dioxide; this gives rise to poor opacity observed in solvent paints formulated with these extenders [16].

Specific Gravity:

Akwaibom (Iba Oku) clay had a specific gravity of 2.43, the references pigment titanium dioxide used in this study with has a specific gravity of 4.20. Settling tendency of paints decreases as the specific gravity reduces, with higher oil absorption. This is because specific gravity of any extender pigment affects the oil absorption and settling tendency of the extender pigment [17, 18]. The specific gravity of some extender pigments are 2.70 whiting, 2.55 calcium carbonate, 4.25 - 4.50 barytes [19,20], and 2.60 China clay[21]. Cost is saved when pigments are of low specific gravity in coatings.

Oil Absorption:

Oil absorption of extender pigment means the need lesser resin in a paint formulation. [22]. Akwaibom (Iba Oku) clay has oil absorption of 38g/100g while titanium dioxide has an oil absorption value of 18.5g/100g, lower than that of Akwaibom (Iba Oku) clay. The oil absorption of a coating pigment is dependent on the size and shape of the pigment particles which affects some coating properties the paint will posses such as film durability, and flow characteristics [23, 24].

Chemical Composition:

X-ray fluorescence (XRF) analysis of akwaibom (Iba Oku) clay showed silicon and aluminium, which formed the dominate backbone of clay molecular structure serving as the main elemental constituent of the clay sample. Silicon and aluminum have 58.19 and 35.35 weight percentages respectively. Also detected in smaller quantities are presence of iron at 7.66%, antimony at 4.54% , silver at 2.62% and titanium oxide (TiO_2) (4.56 wt.%) in that order. Oxide of potassium (K_2O) and iron (iii)(Fe_2O_3) were 0.93, and 2.52 wt.% was present. Utilization of an extender as pigment for paint manufacture is to a great extent dependent on the nature of kaolinite. The unreactive oxides in the clay offers it anti-corrosive properties when used in paint formulation as these unreactive oxides tends to slow down the permeation of reactive species into the painted surface offering it resistance to corrosion of the painted metallic surface.

Resistance to Chemicals:

The present study shows that the stability to chemicals of Akwaibom (Iba oku) clay was not in doubt both in cold and in heated conditions since it did not change colour or dissolve in the chemical media. However, there was visible solubility and colour change in the clay under sulphuric acid medium when heated, thus discouraging the possible use of paints formulated with Akwaibom (Iba oku) clay in acid prone environment. The appreciable quantities of SiO2 (58.19 wt.%) and Al2O3 (35.35 wt.%) in the clay may be given the credit for offering the stability the clay possess in the chemical media studied since these two components have high melting points (SiO2, 1713°C; Al2O3, 2054°C), and are insoluble in water, and mineral acids [25]. The good resistance of Akwaibom (Iba oku) clay to the chemicals studied also show that paints formulated with it will offer good weather resistance if found in the environment where these chemicals exist.

B. Evaluation of Formulated Alkyd Paint Samples with Akwaibom (Iba Oku) clay as Extenders

Time of Surface Dryness:

From graphically representation below in Fig. 2 show that the dry times of the sample paint increased as clay content increased to 30 wt.% clay incorporation, and thereafter, decreased with clay content, and were in the range, 9.8 - 20 mins. The paint sample containing 80 wt.% clay, and TiO2 formulated paint had the same surface dry time of 9.8mins. This is to say that as the amount of sample clay introduced into the formulated alkyd paints it produced good surface drying properties. The addition of Akwaibom (Iba Oku) clay into the alkyd paints sample did not adversely affect the paint's time of surface dryness as surface dry times of a gloss paint is not meant to exceed 6 h from the time of application according to Nigeria Industrial Standards, (NIS)[26].

Table2: Summary for Surface Dryness, Film Thickness, Complete Drying Time and Film Adhesion

Clay Content wt%	Surface dryness (min)	Film Thickness	Complete drying Time (min)	Film Adhesion
0	10	0.15	270	6.3
20	18.8	0.11	350	24.5
30	21.5	0.09	360	20
40	19.6	0.148	380	3.5
50	19.1	0.1	400	6.2
60	16.3	0.149	370	3
70	12.8	0.148	255	3
80	9.8	0.15	220	3

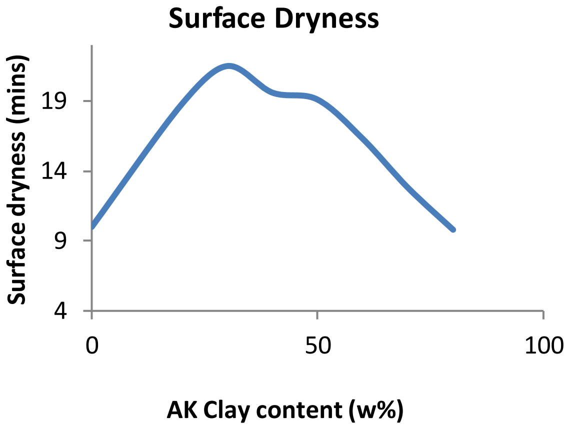

Fig. 2: Effect of Akwaibom (Iba Oku) Clay Content on Time of Surface Dryness of Alkyd Paints.

Dry Film Hardness and Dry Paint Film Thickness:

Dry film hardness of Akwaibom (Iba Oku) clay used in the formulated paint increased with increase in clay content. The reference extender TiO2 formulated paint sample showed the least paint dry film hardness. The paint samples containing 60, 70 and 80 wt. % clay had maximum pencil hardness of 5H. This study represent that the formulated alkyd paint samples showed good hardness property presenting its ability to effectively make binder and pigment particles attract.

On the other hand, the dry paint film thickness of the formulated alkyd paint samples showed from the plot in Fig. 3 that there were no defined orders of variations of paint film thickness with Akwaibom (Iba Oku) clay content. The TiO2 formulated paint, and paint samples containing 40,and 70 wt.% clay had the same film thickness of 0.148mm 60 and 80 wt.% had 0.15mm. Paint samples containing 20, 30 and 50 wt.% clay had the best film thickness of approximately 0.10 mm. The film thickness of a coating defines its extent of durability. In this study, the film thicknesses obtained were in the range, 0.10 - 0.15 mm indicate that Akwaibom (Iba Oku) clay when incorporated into the formulated paint samples will function as a good anti-corrosive paint. This is because; paint film thickness of more than 20 µm has been reported to function well as a barrier resistant to weathering [27].

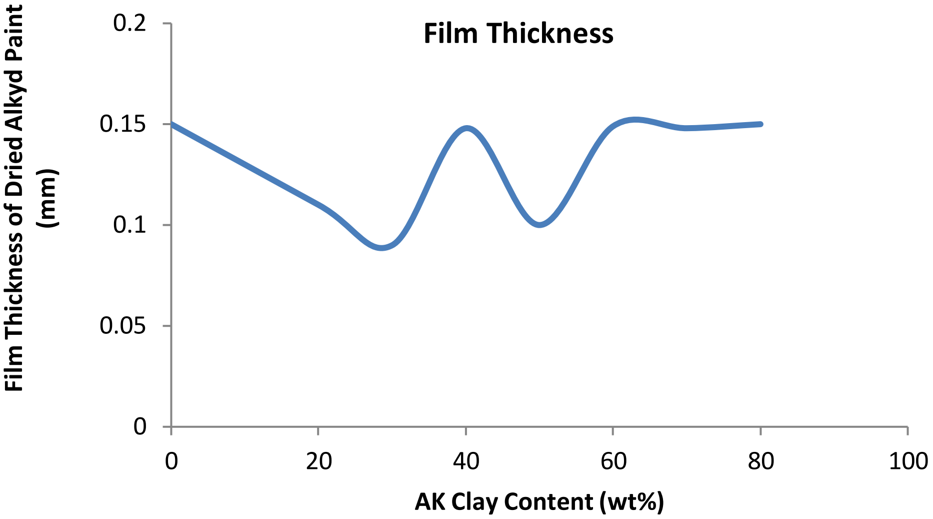

Fig. 3: Effect of AK Clay Content on Film Thickness of Dried Akwaibom (Iba Oku) Clay-Alkyd Paints.

Complete Drying Time:

Figure 4 shows that the incorporation of Akwaibom (Iba Oku) clay into the alkyd paint samples increased the complete drying times, up to 40 wt.% clay incorporation, and later decreased with addition of the clay into the paints. TiO2 formulated paint sample had a through dry time of 270 mins. The formulated alkyd paint having 80 wt.% Akwaibom (Iba oku) clay had the best complete drying time of 220 mins. The formulated alkyd paint samples had good complete drying times as it conforms to Nigeria Industrial Standards (NIS, 1989), which validates that a good gloss paint must have complete drying time not exceeding 24hrs from the time of application.

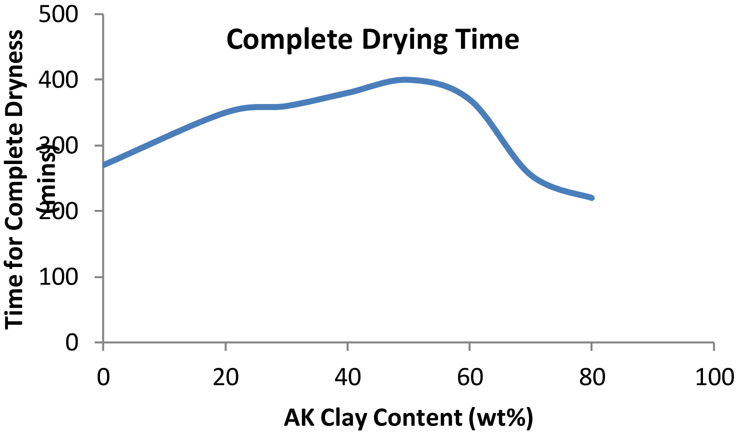

Fig. 4: Effect of AK clay Content on Complete Drying Time of Akwaibom- Alkyd Paints

Adhesion of Paint Films to Substrate:

According to ASTM D 907(2012), adhesion is the state in which two surfaces are held together by interfacial forces which may consist of valence forces or interlocking action or both. Data on the adhesion of the paint films to mild steel panels illustrated in Fig. 5 showed no definite order of variation of paint film's adhesion with clay content. TiO2 formulated paint had an adhesion percentage loss of 6.3, while paint sample containing 50 wt. % clay was at 6.2. There was a sharp spike in adhesion percentage loss of 25 and 24.5 at 20 and 30 wt. % of Akwaibom (Iba Oku) clay when introduced into the alkyd paint, after which the alkyd paint showed a decrease in film adhesion losses as the Akwaibom (Iba Oku) clay content increased. The paint had good adhesion showing good property of gloss paint [26, 27].

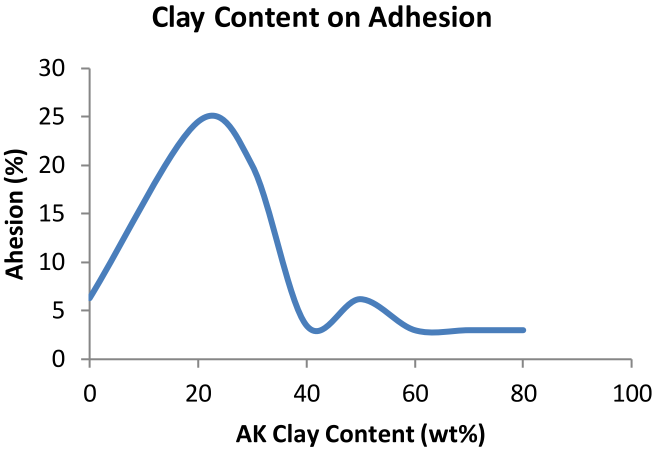

Fig. 5: Effect of Clay Content on Adhesion of Akwaibom clay -Alkyd Paints.

Resistance of Paint Dry Films to Chemicals:

The dry paint film samples resistance to distilled water and 2.5% chemicals such as NaCl, Na_2CO_3 and H_2SO_4 were observed visually at regular intervals of time on immersion in these chemicals and distilled water. Dry paint film samples responses were recorded in tabular form in Table 2. This result showed that Akwaibom (Iba Oku) clay has good attributes to a corrosion protection to mild steel in a salty environment as no blistering or other film defects were noticed on the paint films having Akwaibom (Iba Oku) clay, except for the very slight change in colour observed in the formulations. This attributes can be due to the possible presence of unreactive oxides of Si, Al, Fe in the clay extender sample which prevented the initiation of corrosive species into the substrate film layer thereby inhibiting the corrosion on mild steel. From reports, pigments of TiO2 have been coated with silica and alumina to improve its durability [12,25]. Akwaibom (Iba Oku) clay in the paints provided a sound barrier on metal substrate against corrosive species. From Table 2, the alkyd paint samples did well in distilled water, with satisfactorily responses in Na_2CO_3 but generally, the alkyd paint had a poor response to H_2SO_4 except for the alkyd paint having 40, and50 wt.% of Akwaibom (Iba Oku)clay showing fairly good performance on immersion. The good performances of the alkyd paints in NaCl proves the presence of anti-corrosive property but will not be recommend in a medium were H_2SO_4 exist except the Akwaibom (Iba Oku)clay content is up to 40, and 50 wt.% in the formulation[25-27].

Table 3 shows that the mild steel is not protected from oxidization and surface etching that strong acid initiate which tends to compromises the strength of the mild steel. In the NaCl medium, the paint sample inhibited possibility of providing electrolyte which promotes oxidation and pitting that enhances the occurrence corrosion process especially if the steel is to be used in water. [15] Na2CO3 has some insulative effect with this paint sample it provided more insulation effective enough to prevent corrosive reactions.

Table 3: Resistance of Dry Paint Films to Chemicals

Sample Code	Distilled water	Na2CO3 (2.5%)	NaCl (2.5%)	H2SO4 (2.5%)
APT-AK -100	1	1	2	4
APT-AK-80/20	0	1	1	4
APT-AK-70/30	0	1	1	4
APT-AK -60/40	0	0	1	2
APT-AK -50/50	0	0	0	2
APT-AK -40/60	1	1	1	3
APT-AK -30/70	0	1	1	4
APT-AK -20/80	1	1	1	4

NOTE:
0 = No effects 1 = Very slight effect (colour/wrinkling) 2 = Slight effect (wrinkling)
3 = Effect (blistering/peeling) 4 = Bad effect (blistering/peel)

4. CONCLUSION

AkwaIbom (Iba Oku) clay showed good stability to heat and chemicals having inert oxides of silica, alumina, and titanium dioxide the formulated alkyd paints using the clay have anti-corrosive property. AkwaIbom (Iba Oku) clay was incorporated into the formulated alkyd paints at extender contents, at a weight percentage range of 0 to 80, having a particle size of 0.075mm. Results showed that the formulated alkyd paints showed good surface dryness/covering, and complete or through -dry times, with the best dry time was achieved when 80 wt.% of the clay when added into the alkyd paints. TiO2 formulated paint had the same surface dryness time of10mins, at 70wt.% of Akwaibom(Iba Oku) clay it was 12 mins but only alkyd paint having 80wt.% of Akwaibom (Iba Oku) clay had same surface dryness time with TiO2.

REFERENCES

[1] Odozi, T. O., Dore R., Onu, C. O., 1986. Paint Extenders Based Upon an Indigenous Clay, Journal of Nigerian Society of Chemical Engineering, 5(34-40)

[2] Imerys. 2017. Saving TiO2 in Alkyd Gloss Paints with PolsperseTM10, Imerys Performance Minerals. www.imerys-performance.com

[3] McGuffog, R., 1995. The Use and Advantage of Modified Clay in Improving Dispersion in Solvent Based Paints. ECC International Europe, Cornwall.

[4] Humphrey J. P., Boyd. D., E.2011. Clay: Types, Properties and Uses, Nova Science Publishers, New York.

[5] Velde. B. Composition and Mineralogy of Clay Minerals. In: B. Velde (ed.), "Origin and Mineralogy of Clays",Springer-Verlag, New York, pp. 8-42.

[6] Hideomi K. 2015. Physical and Chemical Properties of Clay, Encyclopedia Britannica. www.britannica.com

[7] Brighatti, M. F., Galan E., Theng. B. K. G.2006.Structures and Mineralogy of Clay Minerals, In: F. Bergaya, B. K. G.Theng, and G. Legaly (eds). Handbook of Clay Science 5. Elsevier, Netherlands, pp. 19-86.

[8] Ahmed, N. M.,2013. Comparative Study on the Role of Kaolin, Calcined Kaolin and Chemically Treated Kaolin in Alkyd-Based Paints for Protection of Steel, Pigment and Resin Technology, 42(1) 3-14.

[9] Ewulonu, C. M., Igwe, I. O., Onyeogoro, G. N.,2016. Performance of Local Clays-Titanuim Dioxide Core-Shell Extender Pigments in Alkyd Paints, Advances in Nanoparticles, 5, 90-102.

[10] Rahim, M., Prasad, M., Gandhi S., Purwar. R.,2020. Effects of Montmorillonite Clay on the Properties of PAN Filaments. International Journal of Polymer and Textile Engineering, 7(2) 7-13.

[11] Clay Wikipedia, the Free Encyclopedia.

[12] Gerhard, Z., 2007. China Clay in Paints, Coatings and Printings Inks, Chemical Technology, 6, 1- 4, 2007

[13] Nayaran R., Raju, K. V. S. N.,2000. The Use of Calcined Clay as Part Replacement of Titanium Dioxide in Latex Paint Formulations, Journal of Applied Polymer Science, 77(5) 1029-1036.

[14] PCI (Paint and Coating Industry) Magazine. 2005. A Comprehensive

Understanding of TiO2 Pigment Durability.

[15] Igwe, I.O., Acha, F., Anyaegbu, C., Agwu, G., Ifeacho, V., Esinwoke, W. G., Asiegbu, Nwapa. C. 2020. Formulation of Anti-Corrosive Alkyd Paints Based on Umuahia Clay Extender. International Journal of Polymer and Textile Engineering. 7. 25-30.

[16] Tiwari, S., Saxena, M., 1999. Use of Fly Ash in High Performance Industrial Coatings, British Corrosion Journal, 34, 184-191.

[17] Murray, H. H., 1991. Overview: Clay Mineral Applications. Applied Clay Science, 5(5-6) 379-395.

[18] Obaje, S.O., Omada, J.I., Dambatta, U.A., 2013. Clays and Their Industrial Applications: Synoptic Review. International Journal of Science and Technology, 3, 264-270.

[19] Osabor, V. N., Okafor, P. C., Ibe, K. A., Ayi, A. A.2009. Characterization of Clays in Odukpani, South Eastern Nigeria, African Journal of Pure and Applied Chemistry, 3(5) 79-85, 2009.

[20] Igwe, I. O., Ezeamaku, L. U., 2010. The Use of Local Clays in Alkyd Paint Formulations, Malaysian Polymer Journals, 5, 81-94.

[21] Boxall, J., Von J. A. - Fraunhofer, “Concise Paint Technology”, Chemical Publishing, New York, 1986.

[22] Raheem, A., Olowu, O. A.,2013. Production of Household Paint Using Clay Materials”, International Journal of Engineering Research and Applications, 3(2) 85-93.

[23] Nelson, K. L.2007. Enhanced Performance and Functionality of Titanium Dioxide Papermaking Pigments with Controlled Morphology and Surface Coating, Georgia Institute of Technology, ProQuest.

[24] Obot, O. W., Obot. M. U., 2021. Industrial Analysis of Iba Oku Clay Deposit in Akwa Ibom State, Nigeria. Applied Engineering, 5(2) 66-72.

[25] Tan, O., Yilmaz, L., Zaimoglu, A.S., 2004, Variation of Some Engineering Properties of Clays with Heat Treatment. Material Letters, 58, 1176-1179.

[26] “Standard for Paints and Varnishes Part 3”, Nigerian Industrial Standard(NIS), Lagos, 1989

[27] Laine, R. M., Blohowiak, K.Y., Robinson, T. R., Hope, M. L., Nardi, P., Kampf J., Uhm, J.,1991. Pentacoordinate Silicon Complex from SiO2, Journal of Materials Science and Engineering, 353, 642 – 644.

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